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REV. J. L. ZABRISKIE,

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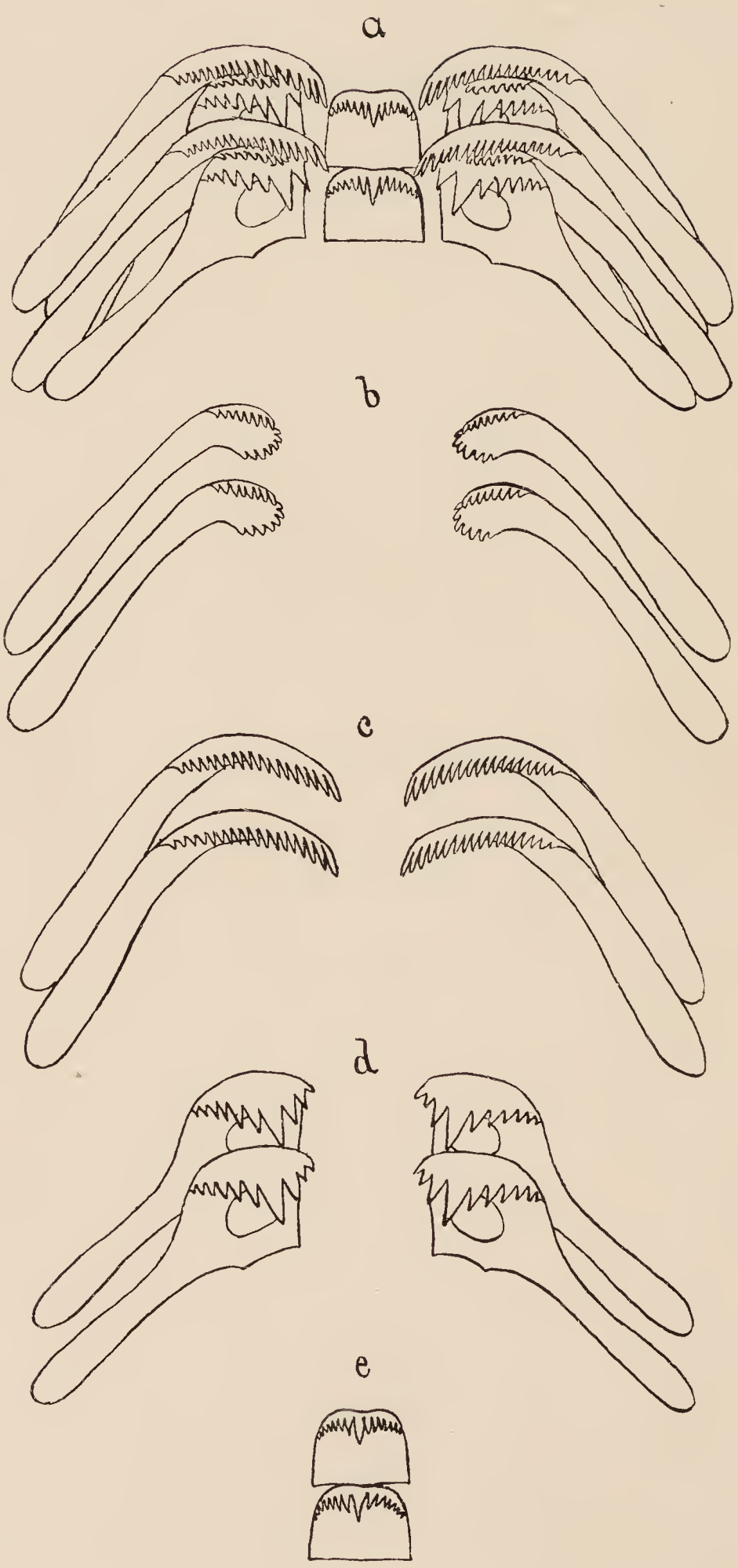


BEECHER ON PYRGULA.

JOURNAL
OF THE
NEW-YORK MICROSCOPICAL SOCIETY.

VOL. VI. JANUARY, 1890. No. 1.

ON THE LINGUAL DENTITION AND SYSTEMATIC POSITION OF PYRGULA.

BY C. E. BEECHER.

(*Read November 1st*, 1889.)

The genus *Pyrgula* has been so often assigned to various families of the mollusca by different authors, that it has had a truly remarkable experience. There now seems to be about an equal weight of opinion as to whether it should be placed in the family Rissoidæ or among the Melaniidæ. Without more definite information than that expressed by the shell, it appears merely a matter of choice as to which group should include the genus. This condition is but one of many, in which development in parallel lines produces forms having great similarity in external appearance, and in which recourse must be had to more important and reliable characters than external form, in order to ascertain their true systematic position.

True systematic data should, if possible, be based upon the assemblage of all the characters of the organism, and it is unsafe to take any one as infallible. In the present genus —*Pyrgula*, and among many similar small turreted and globular shells, as the Rissoidæ, which commonly vary within narrow limits, any important member of the animal which exhibits great

Explanation of Plate 21.

(*a*) Two members of the radula with the teeth in their normal position.

(*b*) The teeth of the second or outer pleural series; showing their spoon-like form

(*c*) The teeth of the first pleural series; carrying eighteen denticles each.

(*d*) The lateral teeth; showing the long slender peduncle, the quadrate body with an alveolus, and the curved serrula bearing ten denticles.

(*e*) Two of the rachidian teeth; showing their form and the arrangement of the denticles.

All figures magnified 500 diameters.

differentiation and is more diversified than the shell, naturally affords a more convenient and trustworthy basis for systematic determination.

Too great reliance may be often placed upon trivial differences in the lingual dentition, but it is believed that within reasonable limits, the characters of the odontophore are extremely serviceable for purposes of classification. Especially is this true for family distinctions, and on this account, such features are commonly recognized as of much, though not of sole, importance

The radula in the Rissoidæ is very characteristic, its principal diagnostic feature being the presence of basal denticles on the rachidian teeth. The accompanying illustration and description of this organ in *Pyrgula annulata*, C. & Jan. (*P. helvetica*, Mich.) the type species of the genus, show that basal denticles are not present on the rachidian tooth, and, therefore, it cannot properly be arranged with the Rissoidæ, but is related to the Melaniidæ.

The genus is at present unknown in North America, as the species which were originally ascribed to it have since been placed in other genera. The first American species thus referred was *Pyrgula scalariformis*, Wolf. (Am. Jour. Conch., vol. v. p. 198, pl. 17, f. 3, 1870) from the Post Pliocene of the Illinois river. This form is now believed to belong to the genus *Pyrgulopsis*, Call and Pilsbry.[1] In 1883, R. E. C. Stearns described a shell from Pyramid Lake, Nevada, and placed it in *Pyrgula* (*P. nevadensis*). The dentition of this form was described and figured by the writer in 1884,[2] but as, at that time, the true dentition of *Pyrgula* was unknown, no comparisons could be drawn, and the systematic position of the species remained unchallenged. Subsequently Call and Pilsbry (*loc. cit.*) proposed the genus *Pyrgulopsis* for this and allied species based upon conchologic features. The only difference in the shell noted is that *Pyrgula* is bicarinate or multicarinate, while *Pyrgulopsis* is characterized as a unicarinate form.

---

[1]On Pyrgulopsis, a new genus of Rissoid mollusk, with descriptions of two new forms. Proc. Davenport, Acad. Nat. Sci., Vol. V. 1886.

[2]Call and Beecher. Notes on a Nevada shell (*Pyrgula nevadensis*). *American Naturalist*, vol. xviii., pp. 853, 854. 1884.

PYRGULA, Christofori and Jan, 1832.

Type, *Melania helvetica*, Michelin, 1831.

= *Pyrgula annulata*, Christ. & Jan, 1832.

Lingual dentition. The number of longitudinal rows of teeth is seven, arranged 3-1-3, after the formula (15–18–10)–15 –(10–18–15).

The rachidian tooth is longitudinally semi-elliptical, with the sides nearly at right angles to the line of the base. Serrula abruptly curving forward, and bearing about fifteen denticulations. The central denticle is the largest and most prominent. The lateral series diminish rapidly in descending order, so that the denticles on the sides of the tooth are very small.

Body of lateral tooth subquadrate, with an angular projection at the basal margin, and a subovate thin alveolus in the central portion. Peduncle slender. Serrula with ten denticles; the fourth from the inner end of the series is much the largest.

The first pleural has about eighteen denticles on the serrula. The second is spoon-shaped, and bears about fifteen denticles.

The shell from which the radula was obtained for this description is from Italy. It was kindly furnished the writer by Wm. H. Dall, Honorary Curator Department of Mollusks, U. S. National Museum.

AMPLIFICATION IN MICROMETRY.

BY HON. MARSHALL D. EWELL, LL. D.

(*Read December 20th*, 1889.)

My attention has quite recently been drawn to this subject in connection with the celebrated "Dr. Cronin case." It may be taken for granted that one cannot measure what he cannot see. But how high an amplification is necessary in a given case is a matter of much importance. In the measurement of blood-corpuscles in medico-legal cases the late Dr. Richardson advocated the use of a very high power, viz.: a $\frac{1}{25}$ or $\frac{1}{50}$ objective. In my own measurements of blood-corpuscles I have out of respect to authority, always used a high power, from 1,500 to 1,800 diameters. Recent experience has, however, qualified my views upon the subject, and in the case of the comparison of the ultimate subdivisions of a micrometer, ruled on metal, I am now of the opinion, that practically the same result may be obtained by the use of a $\frac{1}{4}$ objective as with a $\frac{1}{18}$ or $\frac{1}{25}$.

In December, 1885, I commenced the investigation of the $\frac{1}{100}$ mm. spaces of "Centimeter A." ; but was unable to finish it. Two series of measurements were then made with a Bausch & Lomb opaque illuminating objective, and a Bullock filar micrometer. Recently I have measured the same spaces with a Spencer $\frac{1}{10}$ and $\frac{1}{25}$, and with a Zeiss $\frac{1}{18}$. The results of these measurements are given in the table below, each correction being the mean of from three to twelve readings of the filar micrometer at each end of the measured space.

It will be observed that the agreement between the several series of the writer and the results obtained by Prof. Hilgard is quite close, the discrepancy being practically insensible.

Provided the amplification is sufficient to render the object to be measured of a sensible size, and to render the difference between the sizes of two objects visible, my own judgment is that little, if anything, is gained by the use of a power so high as to impair the definition, even though such impairment be but slight. Quite as much, in other words, is lost by impairment of definition as is gained by increase of amplification. The practical conclusion then is that no higher power should be used than is consistent with perfect definition.

Table of Measurements of "Centimeter A."

Date.	Objective.	Value of 1 div. of mic.	2d $\frac{1}{100}$ mm.	3d	4th	5th	6th	7th	8th	9th	10th	11th	Remarks.
Dec. 26 and 27, 1885.	$\frac{1}{4}$ Bausch & Lomb.	0.126 μ	+0.38 μ	−0.01 μ	+0.05 μ	−0.39 μ	+0.14 μ	+0.27 μ	−0.14 μ	−0.12 μ	+0.09 μ	−0.26 μ	Bullock filar micrometer and Smith's vert. illuminator.
Sept. 12, '89	$\frac{1}{18}$ Zeiss.	0.01651 μ	+0.36	+0 02	+0.06	−0.42	+0.15	+0.28	−0.25	−0.07	+0.08	−0.21	Zentmayer filar micrometer and Smith's vert. illum.
" "	"	0.02166 μ	+0.33	0.00	+0.04	−0.41	+0.15	+0.25	−0.22	−0.14	+0.20	−0.22	Bullock filar micrometer and Smith's vert. illuminator.
Sept. 15, '89	$\frac{1}{25}$ Spencer.	0.02071 μ	+0.31	−0.05	+0.05	−0.43	+0.17	+0.32	−0.21	−0.06	+0.11	−0.19	Bullock filar micrometer and Smith's vert. illuminator. Collar correction = 10°.5.
" 18, '89	$\frac{1}{10}$ "	0.0401 μ	+0.32	+0.03	+0.03	−0.49	+0.16	+0.27	−0.18	−0.16	+0.20	−0.18	Bullock filar micrometer and Smith's vert. illuminator. Collar correction = 2 Rev. 0.¾.
" 19, '89	$\frac{1}{10}$ "	0.02561 μ	+0.36	−0.01	0.00	−0.47	+0.17	+0.25	−0.23	−0.05	+0.16	−0.18	Bullock filar, Smith's vert. illuminator and Bausch & Lomb amplifier. Cover correc. = 2 Rev. 0.¾.
	Mean.	+0.34	0.00	+0.04	−0.44	+0.16	+0.27	−0.22	−0.10	+0.15	−0.20		
Correction for error of total length..		+0.02	+0.02	+0.02	+0.02	+0.02	+0.02	+0.02	+0.02	+0.02	+0.02	+0.02	This is $\frac{1}{10}$th correction for the 1st $\frac{1}{10}$ mm. = + 0.20 μ.
Total correction.....		+0.36	+0.02	+0.06	−0.42	+0.18	+0.29	−0.20	−0.08	+0.16	−0.19		
Correction for same spaces as per report of Professor Hilgard.....		+0.34	+0.05	+0.09	−0.41	+0.20	+0.39	−0.19	−0.05	+0.20	−0.18		

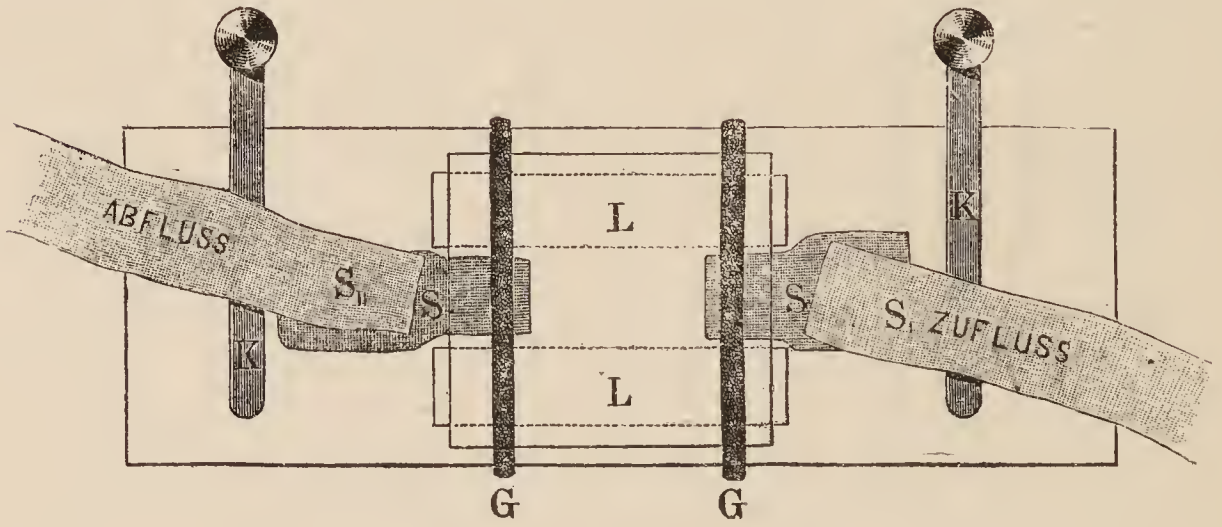
ON CULTIVATING LIVING ORGANISMS UNDER THE MICROSCOPE.

BY E. A SCHULTZE.

[Abstract and translation from an Article by Dr. John af Klercker in *Zeitschrift für Wissenschaftliche Mikroskopie*, vi. 2, p. 145 (1889).]

(*Read October 18th*, 1889.)

Any one, at all familiar with the microscopical study of living organisms, will have met with the difficulty of making a satisfactory examination, on account of the globular shape of the liquid containing the culture. It is well known that, in order to bring the objects to a full state of development, the water, especially in the case of algæ, must often be changed.

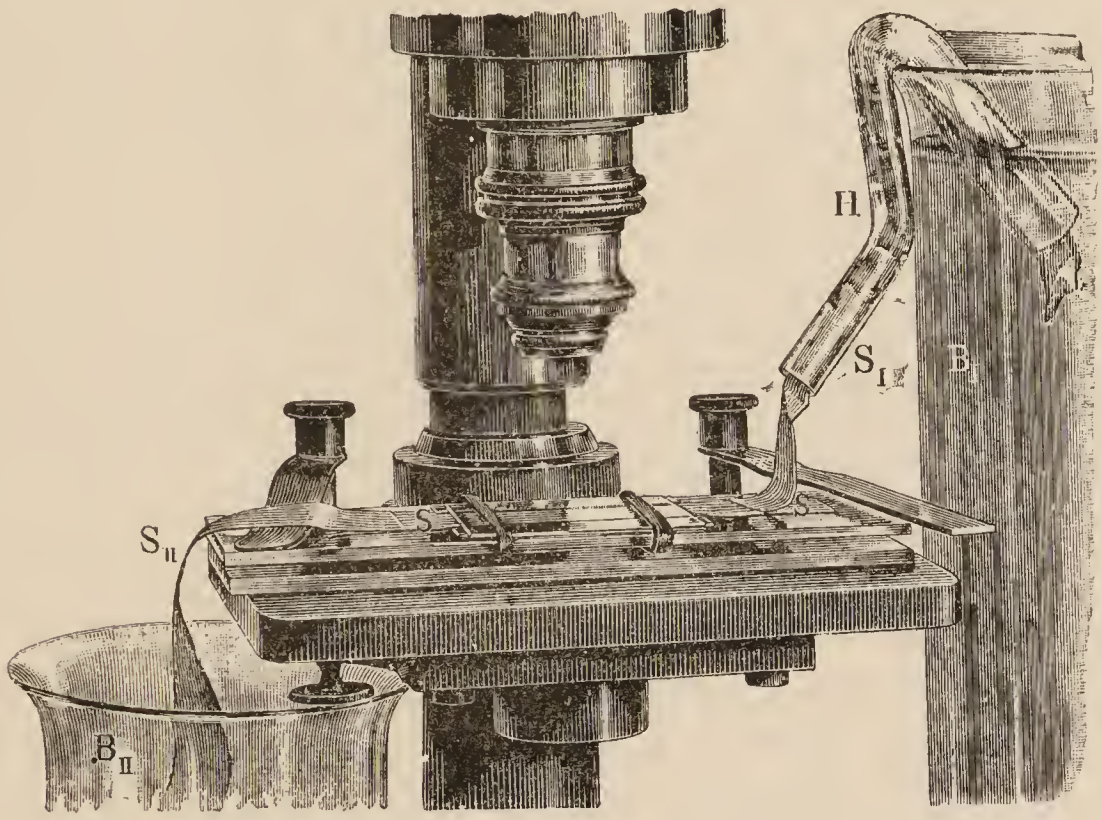


1

In doing this, it is in most cases difficult to prevent the algæ from changing their position under the cover-glass. Consequently a filament under observation may be lost to view. Sometimes, when a too sudden evaporation is feared, the volume of the drop must be increased to such extent that the high-power objectives, and especially the homogeneous immersion lenses, can only be used on those filaments which lie nearest to the cover-glass.

To obviate this difficulty I have been using an apparatus, the construction of which admits of a constant flow of water, and I find that it answers to my entire satisfaction in every

particular. Two strips, of equal length and breadth, say one inch long and one-quarter of an inch wide, cut from the ordinary square thin cover-glass, are cemented to a slide with Canada-balsam, as seen in Fig. 1, L, L. The object is now placed in a large drop of water between these two strips, under a one inch square cover-glass, and the entire capillary space



2

may be filled, if necessary, by adding a few more drops of water.

Two short strips of linen, S, S, are now inserted, one at each end, and are held in position by two rubber bands, passing over the cover-glass and around the slide. In order to secure a flat surface on the under side, the slide is now cemented to another slide by means of two pieces of wax, equal in diameter to that of the rubber bands.

A glass (Fig. 2 B, 1.), reaching about three inches above the stage of the microscope, is filled with water, and a glass siphon inserted, the shorter arm of which has a much smaller opening than the longer. After filling the siphon with water, a strip of linen is gradually forced into the longer arm, till the flow of water is reduced to dropping. The linen strip is now cut the required length, and connected with one of the short pieces at

the side of the cover-glass. The water glass may be covered, to exclude any particles of dust. In this way a constant and steady flow of water is secured. The over-flow is carried, by means of another linen strip, from the opposite end of the cover-glass into a small receptacle at the foot of the microscope.

The following are the advantages of the apparatus :

1. A constant flow of fresh water, which may be regulated by the linen strip in the siphon. The water, while running, keeps saturated with oxygen, by means of the linen strip extending from the mouth of the longer arm of the siphon. This strip also acts as a filter, retaining any particles of dust, that may have accumulated in the reservoir.

2. The height of the capillary space between the cover-glass and the slide being only of the thickness of an ordinary cover-glass, all objects may easily be seen with an immersion lens.

3. The immersion fluid may be removed from the cover-glass without disturbing the objects.

PROCEEDINGS.

Meeting of October 4th, 1889.

The President, Mr. Charles F. Cox, in the chair.

Thirty persons present.

The Recording Secretary read a Paper, presented by Mr. P. H. Dudley, and entitled "Note on *Calotermes marginipennis*, Latr." This Paper is published in the Journal, Vol. V., p. 111.

Mr. Stephen Helm, of No. 417 Putnam Avenue, Brooklyn, N. Y., read a Paper, entitled, "Note on the binary subdivision of *Micrasterias denticulata* (Breb.), Ralfs," illustrated by blackboard sketches and an exhibit, as announced below. This Paper is published in the Journal, Vol V., p. 93.

OBJECTS EXHIBITED.

1. Spores of the Fungus, *Ustilago utriculosa*, Tul., on *Polygonum Pennsylvanicum*, L.: by J. L. Zabriskie.
2. Spores of the Fungus, *Ustilago Austro-Americana*, Speg., on *Polygonum Pennsylvanicum*, L.: by J. L. Zabriskie.
3. Insect eggs, arranged: by Charles S. Shultz.
4. Transverse section of ovary of the Poppy: by Charles S. Shultz.
5. *Volvox stellatus*, Wolle: by William G. De Witt.
6. Two forms of the same, with changed color: by William G. De Witt.
7. Foot of the Beetle, *Chrysochus auratus:* by F. W. Leggett.
8. Two hairs from the foot of the same: by F. W. Leggett.
9. *Micrasterias denticulata* (Breb.), Ralfs: by Stephen Helm.
10. *Plumatella repens:* by Stephen Helm.
11. *Lophopos crystallinus:* by Stephen Helm.

Mr. Zabriskie stated concerning his exhibits, that these fungi infest the same species of plant, *Polygonum Pennsylvanicum*. *Ustilago utriculosa*, as its specific name indicates, causes the fruit of the host to enlarge like a bladder—externally smooth and of a leaden hue, internally a mass of dark purple spores.

These spores are ornamented with prominent ridges, forming pentagons and appearing at the contour of the spore like the cogs of a gear-wheel. *U. Austro-Americana* affects the fruit, stems and leaves of the host. It sometimes causes the whole spike of the host to become a red, hardened, distorted, varnished mass. The spores are spherical, have the surface furnished with delicate spines, and ooze out in tendrils, which latter are sometimes one-half of an inch in length. This last species was described by Spegazzini, of the Argentine Republic, and was not reported from our Eastern States until these specimens were collected in 1888. Both species were abundant at Flatbush, L. I., in that year, but they have been comparatively scarce during this year.

Mr. Leggett said that his exhibit of the foot of the beetle, *Chrysochus auratus*, showed how the insect is able to walk inverted upon glass. The foot looks like a hair-brush, being furnished with numerous hairs, which are evidently provided at the end with a sucker.

Meeting of October 18th, 1889.

In the absence of the President and the Vice-President, Mr. William Wales was elected President *pro tem.*

Twenty-nine persons present.

Mr. J. Beaumont was elected a Corresponding Member, and Messrs. Henry F. Crosby and Bashford Dean were elected resident members of the Society.

Mr. E. A. Schultze read a Paper, which was an abstract and a translation from an article by Dr. John af Klercker, in *Zeitschrift für Wissenschaftliche Mikroskopie*, vi., 2, p. 167 (1889), entitled "On cultivating living organisms under the Microscope." This Paper was illustrated by black-board sketches, and is published in this number of the Journal, p. 6.

Mr. Schultze also gave an abstract and translation of an article by Dr. S. Apáthy, in the same number of the same publication, p. 171, as follows :

"A new cement for glycerine mounts.

"In using asphaltum with glycerine mounts, it is preferable, and in most cases necessary, to first prepare a wax cell, which is afterwards covered with the cement, especially if the object

be a larger one than usual. Asphaltum will, moreover, only adhere to well-cleaned glass, and may crack with time. Canada-balsam, which always makes a hard and well-adhering frame, may never dry where it comes in contact with the glycerine, and, if the glycerine layer be not very thin, it will gradually enter under the cover-glass in the shape of a cloudy mass. A glycerine mount framed in Canada-balsam is never safe. It may last for a year or more, but it will eventually deteriorate, as has been my sad experience to witness.

"The cement I have prepared can be used without fear of any of these difficulties occurring. It is composed of equal parts of hard paraffine (melting point 60° C.) and Canada-balsam. They are melted together in a porcelain evaporating dish, and then kept heated over a moderate flame until the mass becomes of a golden color, and emits no more turpentine vapors. When cold the mixture is hard, but it can be readily warmed for use."

Mr. Schultze also gave notice of diatomaceous material found by a fisherman, in the month of June last, floating in the Pacific Ocean, two miles off the coast of Santa Monica, California, and stated that the material was now under examination to ascertain if it contained the same forms as those in the original "Santa Monica Find."

Dr. N. L. Britton read a Paper, entitled "The genus *Eleocharis* in North America." This Paper was illustrated by black-board sketches, and by a series of herbarium specimens and mounts as announced below, and is published in the JOURNAL, Vol. V., No. 4, p. 95.

OBJECTS EXHIBITED.

1. New and old mandibles of *Calotermes marginipennis*, Latr., and cast skin of the nympha of the same. Prepared by J. Beaumont, Colon, S. A.: Exhibited by P. H. DUDLEY.

2. Egg—one day after laying—of *Diplax Berenice:* by L. RIEDERER.

3. Larva of the same, five days old : by L. RIEDERER.

4. Seeds of *Eleocharis mutata* (L.), Rœm. & Schult.: by N. L. BRITTON.

5. Seeds of *E. capitata* (Willd.), R. Br.: by N. L. BRITTON.

6. Pigeon-post film, used in the Franco-Prussian war: by J. D. HYATT.

7. Spores of *Isoetes Englemanni*, Braun: by J. D. HYATT.

MEETING OF NOVEMBER 1ST, 1889.

The President, Mr. Charles F. Cox, in the chair.

Thirty-four persons present.

Mr. Charles S. Shultz introduced to the Society Miss Mary A. Booth, of Longmeadow, Mass., who was present as a visitor.

The President read a Paper, entitled "On the lingual dentition and systematic position of *Pyrgula*," and presented by Mr. Charles E. Beecher, a Corresponding Member of the Society. This paper is published in this number of the JOURNAL, p. 1.

OBJECTS EXHIBITED.

1. Diatoms of the genus *Aulacodiscus*, 29 forms and 19 species; prepared by Möller: by E. A. SCHULTZE.

2. Diatoms of the genus *Aulocodiscus*, 110 forms and 36 species; prepared by Thum: by E. A. SCHULTZE.

3. Fungus affecting shrimp in an aquarium: by F. W. LEGGETT.

4. Diatoms, from Bay of Bengal.

5. Diatoms, from Sandai, Japan.

6. Diatoms, from cementstein of Sandai, Japan.

7. Diatoms, from material found floating two miles off the coast of Santa Monica, California, June, 1889.

8. Diatoms, *Stephanodiscus careonensis* and *Melosira solida*.

9. Diatoms, from Rodondo Beach, California.

These six slides—Nos. 4–9 inclusive—were prepared and exhibited by Miss Mary A. Booth, and were donated by her to the Cabinet of the Society.

On motion, the thanks of the Society were tendered Miss Booth for this donation.

Mr. Leggett stated that he had kept shrimp for the space of four months in an aquarium, and that the fungus exhibited by him was now becoming very destructive to them. Usually a shrimp would die in one night after the appearance of the filaments of the fungus upon its body.

Meeting of November 15th, 1889.

The President, Mr. Charles F. Cox, in the chair.

Forty persons present.

Mr. Charles E. Pellew, E. M., delivered an Address on "The Microscopical and Other Tests for Blood." This Address was illustrated by many chemical experiments, conducted by Mr. Pellew, and by many exhibits, under the direction of Dr. George C. Freeborn and Messrs. G. Müller, C. C. Carmalt and C. F. W. McClure, as announced below.

Objects exhibited.

1. Fresh human blood, in "Holman's Current-slide:" by Charles F. Cox.
2. Circulation of blood in lung of Frog: by Dr. George C. Freeborn.
3. Circulation of blood in mesentery of Frog: by Dr. George C. Freeborn.
4. Human blood in Leucocythæmia, excess of white cells, the number of red cells being reduced by bacteria.
5. Human blood showing *Plasmodium malariæ* in malarial fever.
6. Blood showing *Bacillus* of anthrax.
7. Hæmoglobin crystals from human blood dried six months.
8. Hæmoglobin crystals from fresh blood of White Rat.
9. Blood of Black Bass, double stained.
10. Blood of Robin, double stained.
11. Blood of Frog, double stained.
12. Diluted human blood on a "Blood-cell Counter."
13. Fibrin from fresh human blood.
14. Continuous spectrum.
15. Spectrum of Oxy-Hæmoglobin.
16. Spectrum of reduced Hæmoglobin.
17. Spectrum of Limestone.

Exhibits, Nos. 4–17, inclusive, were under the care of Messrs. Müller, Carmalt and McClure.

Dr. Freeborn described "Thoma's Frog-plates," employed on the occasion.

The thanks of the society were tendered Dr. Freeborn and Messrs. Müller, Carmalt and McClure for their assistance in the matter of these exhibits.

PUBLICATIONS RECEIVED.

The Microscope : Vol. IX., Nos. 10, 11 (October, November, 1889).

The American Monthly Microscopical Journal : Vol. X., Nos. 9, 11 (September, November, 1889).

The Microscopical Bulletin and Science News : Vol. VI., No. 5 (October, 1889).

Bulletin of the Torrey Botanical Club : Vol. XVI., Nos. 9–11 (September–November, 1889).

Anthony's Photographic Bulletin : Vol. XX., Nos. 17–22 (September 14–November 23, 1889).

The Botanical Gazette : Vol. XIV., Nos. 9–11 (September–November, 1889).

The Journal of Mycology : Vol. V., No. 3 (September, 1889).

Entomologica Americana : Vol. V., Nos. 5–9 (May–September, 1889).

Insect Life : Vol. II., Nos. 3, 4 (September, October, 1889).

West American Scientist : Vol. VI., Nos. 47, 48 (September, October, 1889).

New York Academy of Sciences ; Transactions: Vol. VIII., Nos. 5–8 (February–June, 1889).

Academy of Natural Sciences of Philadelphia; Proceedings : 1889. Part 2.

Boston Society of Natural History; Proceedings: Vol. XXIV., Parts 1, 2 (May, 1888–May, 1889).

California Academy of Sciences ; Proceedings: Vol. I., Parts 1, 2 (June, 1888–April, 1889).

Elisha Mitchell Scientific Society; Journal: Vol. VI., Part 1 (January–June, 1889).

Colorado Scientific Society; Proceedings : Vol. III., Part 1 (1888).

Meriden Scientific Association ; Transactions: Vol. III. (1888).

Cincinnati Society of Natural History ; Journal : Vol. XII., Nos. 2, 3 (October, 1889).

The Essex Institute; Bulletin: Vol. XX., No. 7–Vol. XXI., No. 6 (July, 1888–June, 1889).

The San Francisco Microscopical Society ; Proceedings: Meetings of April 24, and Nov. 13, 1889).

Natural Science Association of Staten Island : Proceedings, September 12–November 14, 1889; Index of Vol. I. (1883–1888).

Agricultural College of Michigan : Bulletin, No. 53 (August, 1889).

Agricultural College of Alabama : Bulletin No. 7 (October, 1889).

College of Agriculture of Cornell University : Bulletins 9, 10 (September, October, 1889).

Meteoric Iron from Arkansas, 1886: By George F. Kunz.

Precious Stones: By George F. Kunz. 1888.

Mineralogical Notes: By George F. Kunz. 1888.

Two new masses of Meteoric Iron: By George F. Kunz. 1888.

Precious Stones in Canada and British America. By George F. Kunz. 1888.

Catalogue of Precious Stones of North America. By Tiffany & Co., New York. 1889.

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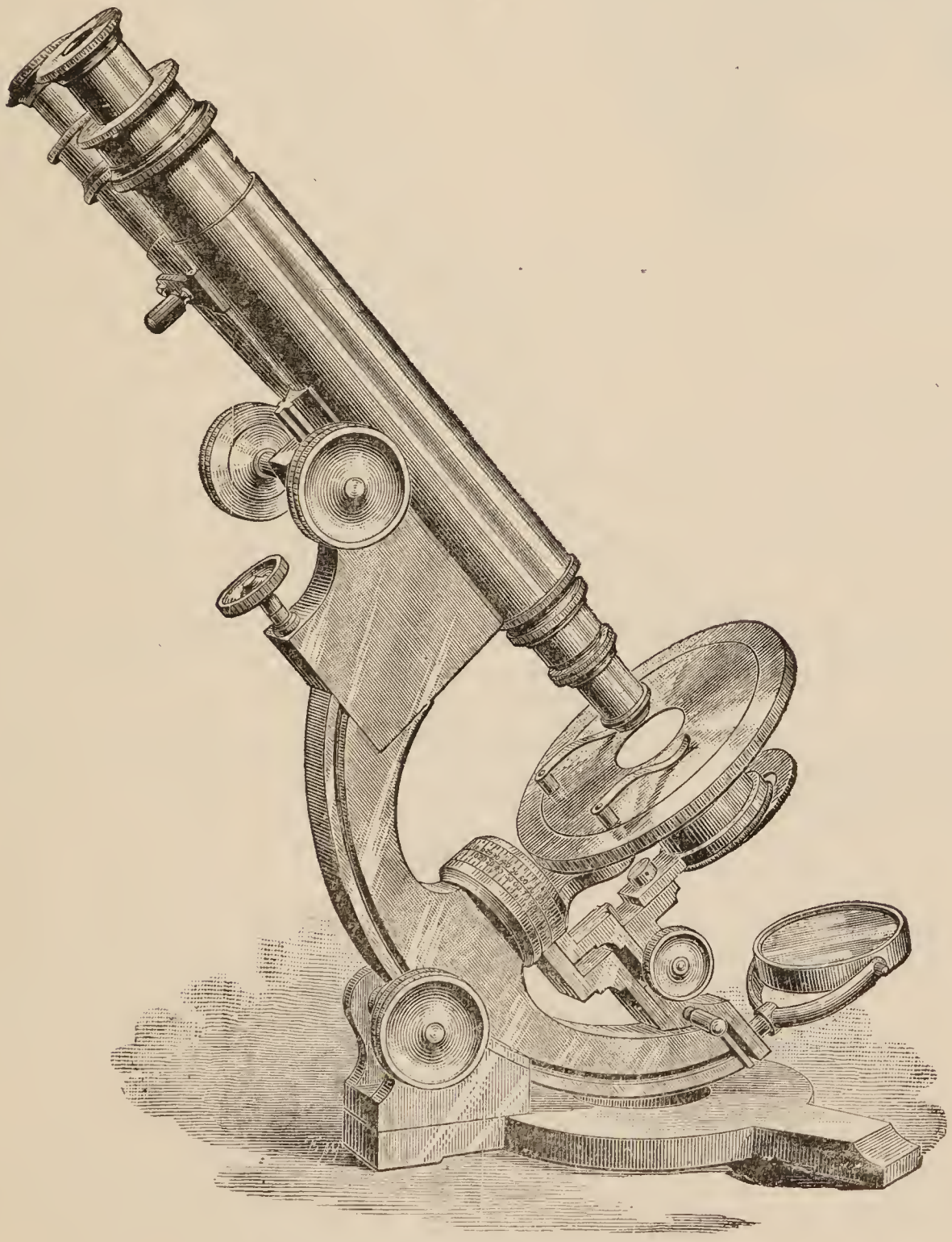

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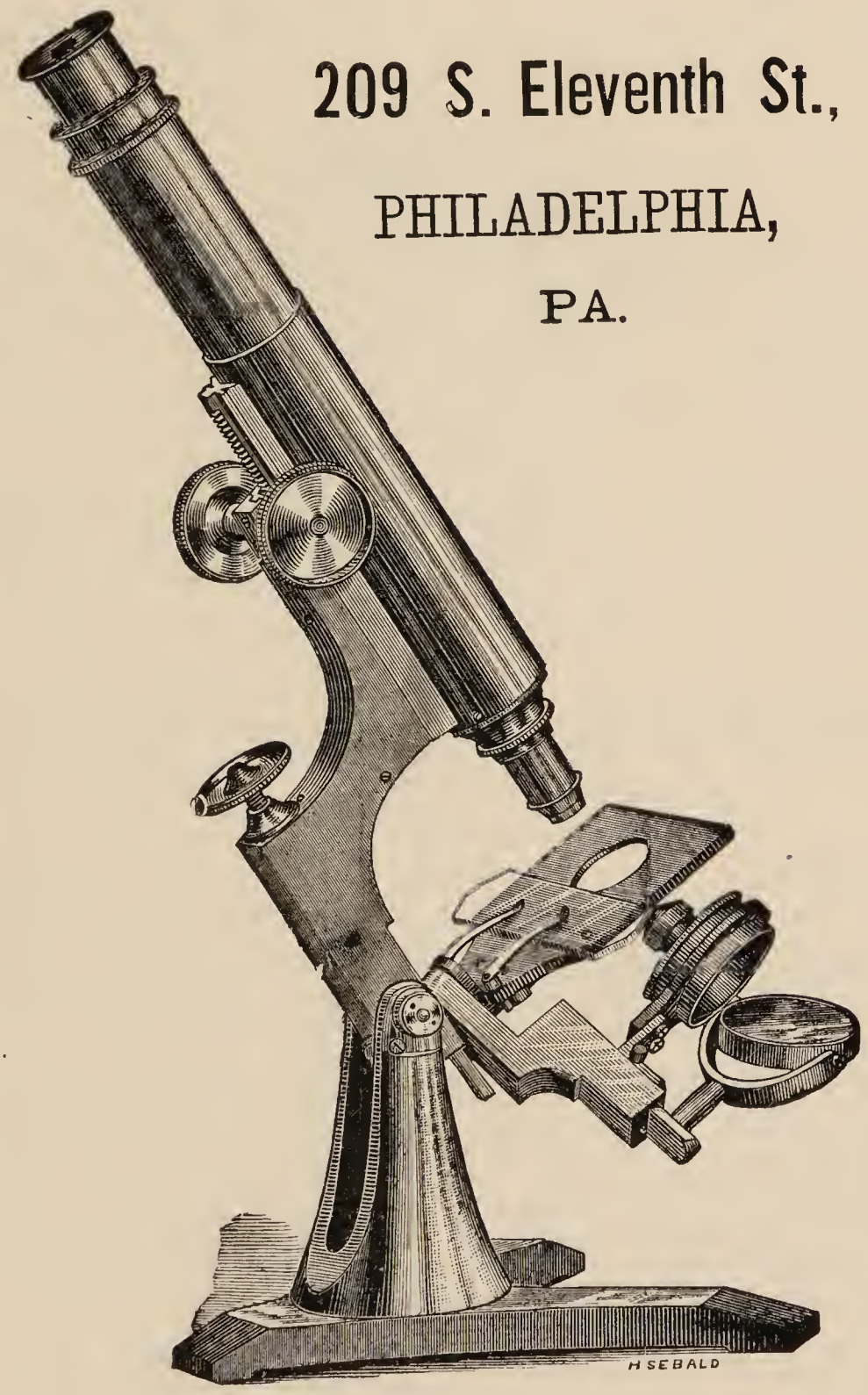

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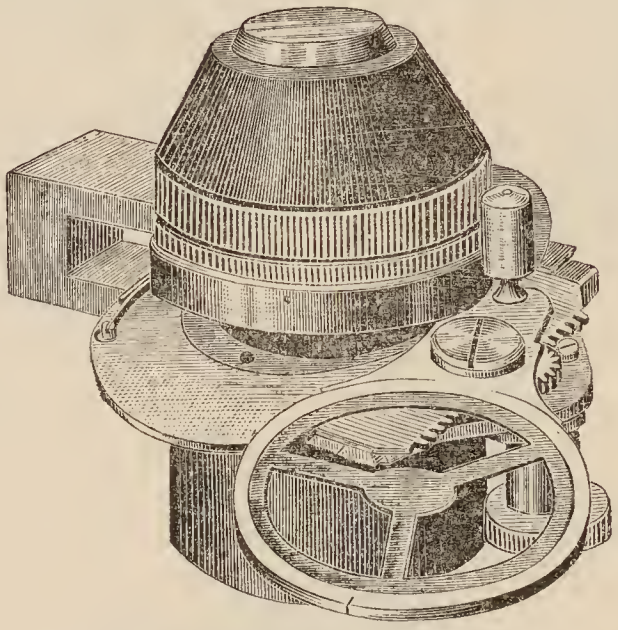

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I. Numerical Aperture Table.*

The "APERTURE" of an optical instrument indicates its greater or less capacity for receiving rays from the object and transmitting them to the image, and the aperture of a Microscope objective is therefore determined by the ratio between its focal length and the diameter of the emergent pencil at the plane of its emergence—that is, the utilized diameter of a single-lens objective or of the back lens of a compound objective.

This ratio is expressed for all media and in all cases by $n \sin u$, n being the refractive index of the medium and u the semi-angle of aperture. The value of $n \sin u$ for any particular case is the "*numerical aperture*" of the objective.

Numerical Aperture. ($n \sin u = a$.)	Angle of Aperture ($= 2u$.)			Illuminating Power. (a^2.)	Theoretical Resolving Power, in Lines to an Inch. ($\lambda = 0{\cdot}5269\,\mu$ = line E.)	Penetrating Power. $\left(\frac{1}{a}\right)$
	Dry Objectives. ($n = 1$.)	*Water-Immersion* Objectives. ($n = 1{\cdot}33$.)	*Homogeneous-Immersion* Objectives. ($n = 1{\cdot}52$.)			
1·52	..	..	180° 0′	2·310	146,528	·658
1·50	..	..	161° 23′	2·250	144,600	·667
1·48	..	..	153° 39′	2·190	142,672	·676
1·46	..	..	147° 42′	2·132	140,744	·685
1·44	..	..	142° 40′	2·074	138,816	·694
1·42	..	..	138° 12′	2·016	136,888	·704
1·40	..	..	134° 10′	1·960	134,960	·714
1·38	..	..	130° 2′	1·904	133,032	·725
1·36	..	..	126° 57′	1·850	131,104	·735
1·34	..	..	123° 40′	1·796	129,176	·746
1·33	..	180° 0′	122° 6′	1·770	128,212	·752
1·32	..	165° 56′	120° 33′	1·742	127,248	·758
1·30	..	155° 38′	117° 34′	1·690	125,320	·769
1·28	..	148° 28′	114° 44′	1·638	123,392	·781
1·26	..	142° 39′	111° 59′	1·588	121,464	·794
1·24	..	137° 36′	109° 20′	1·538	119,536	·806
1·22	..	133° 4′	106° 45′	1·488	117,608	·820
1·20	..	128° 55′	104° 15′	1·440	115,680	·833
1·18	..	125° 3′	101° 50′	1·392	113,752	·847
1·16	..	121° 26′	99° 29′	1·346	111,824	·862
1·14	..	118° 0′	97° 11′	1·300	109,896	·877
1·12	..	114° 44′	94° 56′	1·254	107,968	·893
1·10	..	111° 36′	92° 43′	1·210	106,040	·909
1·08	..	108° 36′	90° 33′	1·166	104,112	·926
1·06	..	105° 42′	88° 26′	1·124	102,184	·943
1·04	..	102° 53′	86° 21′	1·082	100,256	·962
1·02	..	100° 10′	84° 18′	1·040	98,328	·980
1·00	180° 0′	97° 31′	82° 17′	1·000	96,400	1·000
0·98	157° 2′	94° 56′	80° 17′	·960	94,472	1·020
0·96	147° 29′	92° 24′	78° 20′	·922	92,544	1·042
0·94	140° 6′	89° 56′	76° 24′	·884	90,616	1·064
0·92	133° 51′	87° 32′	74° 30′	·846	88,688	1·087
0·90	128° 19′	85° 10′	72° 36′	·810	86,760	1·111
0·88	123° 17′	82° 51′	70° 44′	·774	84,832	1·136
0·86	118° 38′	80° 34′	68° 54′	·740	82,904	1·163
0·84	114° 17′	78° 20′	67° 6′	·706	80,976	1·190
0·82	110° 10′	76° 8′	65° 18′	·672	79,048	1·220
0·80	106° 16′	73° 58′	63° 31′	·640	77,120	1 250
0·78	102° 31′	71° 49′	61° 45′	·608	75,192	1·282
0·76	98° 56′	69° 42′	60° 0′	·578	73,264	1·316
0·74	95° 28′	67° 36′	58° 16′	·548	71,336	1·351
0·72	92° 6′	65° 32′	56° 32′	·518	69,408	1·389
0·70	88° 51′	63° 31′	54° 50′	·490	67,480	1·429
0·68	85° 41′	61° 30′	53° 9′	·462	65,552	1·471
0·66	82° 36′	59° 30′	51° 28′	·436	63,624	1·515
0·64	79° 35′	57° 31′	49° 48′	·410	61,696	1·562
0·62	76° 38′	55° 34′	48° 9′	·384	59,768	1·613
0·60	73° 44′	53° 38′	46° 30′	·360	57,840	1·667
0·58	70° 54′	51° 42′	44° 51′	·336	55,912	1·724
0·56	68° 6′	49° 48′	43° 14′	·314	53,984	1·786
0·54	65° 22′	47° 54′	41° 37′	·292	52,056	1·852
0·52	62° 40′	46° 2′	40° 0′	·270	50,128	1·923
0·50	60° 0′	44° 10′	38° 24′	·250	48,200	2·000

EXAMPLE.—The apertures of four objectives, two of which are dry, one water-immersion, and one oil-immersion, would be compared on the *angular* aperture view as follows:—106° (air), 157° (air), 142° (water), 130° (oil).

Their actual apertures are, however, as ·80 (air), ·98 (air), 1·26 (water), 1·38 (oil), or their numerical apertures.

* From The Journal of the Royal Microscopical Society.

II. Conversion of British and Metric Measures.

(1.) Lineal.

Micromillimetres, &c., into Inches, &c.

μ	ins.	mm.		ins.	mm.		ins.
1	·000039	1		·039370	51		2·007892
2	·000079	2		·078741	52		2·047262
3	·000118	3		·118111	53		2·086633
4	·000157	4		·157482	54		2·126003
5	·000197	5		·196852	55		2·165374
6	·000236	6		·236223	56		2·204744
7	·000276	7		·275593	57		2·244115
8	·000315	8		·314963	58		2·283485
9	·000354	9		·354334	59		2·322855
10	·000394	10	(1 cm).	·393704	60	(6 cm.	2·362226
11	·000433	11		·433075	61		2·401596
12	·000472	12		·472445	62		2·440967
13	·000512	13		·511816	63		2·480337
14	·000551	14		·551186	64		2·519708
15	·000591	15		·590556	65		2·559078
16	·000630	16		·629927	66		2·598449
17	·000669	17		·669297	67		2·637819
18	·000709	18		·708668	68		2·677189
19	·000748	19		·748038	69		2·716560
20	·000787	20	(2 cm.)	·787409	70	(7 cm.)	2·755930
21	·000827	21		·826779	71		2.795301
22	·000866	22		·866150	72		2·834671
23	·000906	23		·905520	73		2·874042
24	·000945	24		·944890	74		2·913412
25	·000984	25		·984261	75		2·952782
26	·001024	26		1·023631	76		2.992153
27	·001063	27		1·063002	77		3·031523
28	·001102	28		1·102372	78		3·070894
29	·001142	29		1·141743	79		3·110264
30	·001181	30	(3 cm.)	1·181113	80	(8 cm.)	3·149635
31	·001220	31		1·220483	81		3·189005
32	·001260	32		1·259854	82		3·228375
33	·001299	33		1·299224	83		3·267746
34	·001339	34		1·338595	84		3·307116
35	·001378	35		1·377965	85		3·346487
36	·001417	36		1·417336	86		3·385857
37	·001457	37		1·456706	87		3·425228
38	·001496	38		1·496076	88		3·464598
39	·001535	39		1·535447	89		3·503968
40	·001575	40	(4 cm.)	1·574817	90	(9 cm.)	3·543339
41	·001614	41		1·614188	91		3·582709
42	·001654	42		1·653558	92		3·622080
43	·001693	43		1·692929	93		3·661450
44	·001732	44		1·732299	94		3·700820
45	·001772	45		1·771669	95		3·740191
46	·001811	46		1·811040	96		3·779561
47	·001850	47		1·850410	97		3·818932
48	·001890	48		1·889781	98		3·858302
49	·001929	49		1·929151	99		3·897673
50	·001969	50	(5 cm.)	1·968522	100	(10 cm. = 1 decim.)	
60	·002362						
70	·002756						
80	·003150						
90	·003543						
100	·003937						
200	·007874						
300	·011811						
400	·015748						
500	·019685						
600	·023622						
700	·027559						
800	·031496						
900	·035433						
1000	(= 1 mm.)						

decim.	ins.
1	3·937043
2	7·874086
3	11·811130
4	15·748173
5	19·685216
6	23·622259
7	27·559302
8	31·496346
9	35·433389
10 (1 metre)	39·370432
= 3·280869 ft.	
= 1·093623 yds.	

Inches, &c., into Micromillimetres, &c.

ins.	μ
$\frac{1}{25000}$	1·015991
$\frac{1}{20000}$	1·269989
$\frac{1}{15000}$	1·693318
$\frac{1}{10000}$	2·539977
$\frac{1}{9000}$	2·822197
$\frac{1}{8000}$	3·174972
$\frac{1}{7000}$	3·628539
$\frac{1}{6000}$	4·233295
$\frac{1}{5000}$	5·079954
$\frac{1}{4000}$	6·349943
$\frac{1}{3000}$	8·466591
$\frac{1}{2000}$	12·699886
$\frac{1}{1000}$	25·399772

mm.	
$\frac{1}{900}$	·028222
$\frac{1}{800}$	·031750
$\frac{1}{700}$	·036285
$\frac{1}{600}$	·042333
$\frac{1}{500}$	·050800
$\frac{1}{450}$	·056444
$\frac{1}{400}$	·063499
$\frac{1}{350}$	·072571
$\frac{1}{300}$	·084666
$\frac{1}{250}$	·101599
$\frac{1}{200}$	·126909
$\frac{1}{150}$	·169332
$\frac{1}{100}$	·253998
$\frac{1}{50}$	·507995
$\frac{1}{25}$	1·015991
$\frac{1}{20}$	1·269989
$\frac{1}{16}$	1·587486
$\frac{1}{15}$	1·693318
$\frac{1}{12}$	2·116648
$\frac{1}{10}$	2·539977
$\frac{1}{8}$	3·174972
$\frac{1}{6}$	4·233295
$\frac{3}{16}$	4·762457
$\frac{1}{5}$	5·079954
$\frac{1}{4}$	6·349943
$\frac{5}{16}$	7·937429
$\frac{3}{8}$	9·524915

cm.	
$\frac{7}{16}$	1·111240
$\frac{1}{2}$	1·269989
$\frac{9}{16}$	1·428737
$\frac{5}{8}$	2·587486
$\frac{11}{16}$	1·746234
$\frac{3}{4}$	1·904983
$\frac{13}{16}$	2·063732
$\frac{7}{8}$	2·222480
$\frac{15}{16}$	2·381229
1	2·539977
2	5·079954
3	7·619932

decim.	
4	1·015991
5	1·269989
6	1·523986
7	1·777984
8	2·031982
9	2·285979
10	2·539977
11	2·793975
1 ft.	3·047973

metres.	
1 yd. =	·914392

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